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Date: May 27, 2003

To: Kirk Dimmitt, MWD

From: Byron C. Gabrielsen, Ph.D., CCA

Subject: **Cropping patterns, yield trends, and evapotranspiration as a basis for water requirement estimates within Imperial Irrigation District.**

The Regional Director for the Bureau of Reclamation currently is in the process of formulating his annual recommendations regarding diversion and use of California's 4.4 million acre-feet (MAF) allotment of Colorado River water. Of this allotment, the Imperial Irrigation District (IID) has requested that it be allowed to divert a total 3.1 million acre-feet (MAF) in 2003, which it asserts is the amount needed to satisfy all reasonable beneficial uses within the district. However, Metropolitan Water District (MWD) and others believe the amount requested by IID far exceeds its needs.

Part 417 of the Code of Federal Regulations sets forth various factors the Regional Director must consider in making its recommendations, many of which focus on or relate to the evapotranspiration (ET) demands or needs of the crops being raised, i.e., the amount of water that is consumed via evaporation from the soil and transpiration through the plants. To assist MWD in assessing the merits of IID's request for 3.1 MAF of water, I was asked to conduct an independent evaluation of such ET-related factors. Accordingly, I calculated the number of acres irrigated within the district each year since 1960, assessed the types of crops grown, and evaluated historical yield trends for the primary crops produced in the district. I also examined fluctuations in reference ET (ETo) over a 19-year period to assess how this factor may influence crop water requirements within the region. After consideration of my findings, I have concluded that the ET demand within the district service area is less than what IID claims. My disagreement is based upon; 1) how IID compiles annual crop acreages, 2) recent trends in cropping patterns within the district, and 3) IID's stated misconception of ET-crop yield relationships.

Specifically, my conclusions may be summarized as follows. ***First***, the method in which IID compiles annual crop acreage summaries within the district is flawed. IID determines crop acreages based upon the highest planting month during each calendar year. For annual crops, this approach often misses individual crop cycles (i.e., the period from planting through harvest) in any particular year. For perennial crops, the method ignores fluctuations in planted acres throughout the year and the effect this would have on total water requirements. In contrast, the protocol as applied by the Water Study Team (WST,1998), during their multi-year examination of irrigation water requirements within IID, is preferable since it identifies the maximum planted acres within each crop production cycle (i.e., planting to harvest). Furthermore, the WST method uses the annual average to estimate acreages of perennial crops which allows for fluctuation in planted acres and actual water use of these crops. In summary, IID's method of acreage compilation significantly overstates the total cropped acreage in any given year. As a result, estimates of ET demand within the district are consistently and highly exaggerated.

Second, total irrigated acreage within the IID has historically trended downward, particularly in more recent years. This is attributable to declines in both garden and field crop plantings over the past 20

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Second, total irrigated acreage within the IID has historically trended downward, particularly in more recent years. This is attributable to declines in both garden and field crop plantings over the past 20 years. Although IID has noted significant increases in planted acreage of some crops such as Bermudagrass, the total cropped acres in the district have declined. This trend is an important consideration toward estimating water requirements, since a decline in total cropped acreage should also lead to reductions in total irrigation water requirement. Interestingly, there is no correlation evident between net diversions of Colorado River water into the district and changes in cropped acreage within the IID from 1967 through 2002. This shows that increases in net water diversions into IID have not occurred in response to changes in the number of cropped acres or the types of crops grown.

Third, yield trends within Imperial County from 1980 through 2001 have remained steady or trended upward for most of the primary crops grown. During this time, the regional ETo demand has fluctuated within normal limits. Further analysis comparing the net irrigation requirement calculated under 'standard ideal conditions' against the actual amount of irrigation water consumption on IID lands indicated that crop ET in the IID water service area is at a practical maximum. Thus, claims to increase water deliveries to sustain or improve crop yields have no merit.

Allen (2003b) conducted an assessment of independent ET calculation methods that have been applied to the IID service area in previous studies. His assessment indicates the consistency and reliability of determining actual crop ET estimates within IID, particularly those estimates that are determined by water balance closure. The consistency of these methods proves that determination of actual ET from IID crops is accurate and dependable. These methods are useful for determining future ET requirements within IID when applied to the expected reference ET and cropping pattern.

To summarize, my findings indicate that changes in net diversions of Colorado River water into the IID service area cannot be adequately explained by the observed changes in total cropped acreage, crop types, or the level of crop production (yields) that has occurred during the past several years. It is further evident that IID has consistently over estimated the total acres of crops in their <u>Annual Inventory of Areas Receiving Water</u>. Although crop acreage and crop mixes must be considered when determining future water needs, it's importance is relevant only to the ET demand of the crops grown on those acres. Reliable estimates for determining ET of the crops grown within the district have been developed, and these procedures should provide the primary basis for estimating water requirements within IID.

On the following pages, is a more detailed discussion which addresses those key elements indicated above.

ASSESSMENT OF WATER REQUIREMENTS WITHIN IID

The specific crop mix together with the total acres of crops are collectively considered when determining the total water requirement within IID. This approach necessarily should include estimates of the expected crop ET, leaching requirement, and other irrigation allowances that may be considered reasonable and beneficial for the particular cropping pattern. Methods for estimating crop ET, leaching and reasonable losses within IID have been addressed by others (Allen, 2003a; Allen, 2003b; Rhoades, 2003a; Rhoades, 2003b). In this memorandum, my intent is to focus primarily upon crop acreages, yield trends, and ET-crop yield relationships as they relate to assessments of irrigation water requirements within IID.

Crop Acreage Estimates

The irrigated area within the IID varies each year due to changes in the general cropping pattern and the degree of multiple cropping imposed by growers. Although determination of the total district annual water requirement is influenced by estimates of the irrigation acreage, increases in cropped acres do not necessarily establish a concomitant increase in irrigation water requirement. For instance, most garden crops (used in multiple cropping sequences) require substantially less water relative to that of field or forage crops. Thus, multiple cropping water needs in some years may actually be less than that for mono-crops depending upon the actual crops grown.

Estimates of crop acreages within the IID service area will vary depending upon the method used to compile the crop inventory in any particular year. Prior to 1989, crop acreages were published in the Imperial County Annual Crop Report in cooperation with IID. However, in 1989, IID initiated its own inventory system for determining crop acreages within its service area. These data are compiled each year in a crop survey entitled, IID Annual Inventory of Areas Receiving Water. Using this system, annual acreage estimates for each crop are assumed to be equivalent to the highest number of acres reported for any particular month during the calendar year. This inventory method is used to estimate acreages for both annual and perennial crops. IID's method for determining crop acreages is flawed, however, in that it ignores the normal cropping cycles associated with winter crops (i.e., those crops planted in one year and harvested in the next). In addition, this method only reports the maximum monthly acreage of perennial crops planted in any particular year. This approach gives no consideration to periods during the calendar year in which planted acreage of perennial crops is reduced (such as when a perennial forage has been removed to prepare for a fall vegetable crop), or when water requirements of some acres may be relatively low (e.g., during crop establishment). Application of the method used by IID to compile crop acreages results in a 'maximized acre' estimate in lieu of a more accurate or realistic determination. As a result, subsequent determinations of required irrigation water are always overstated.

In most instances, previous studies of water use within the district have relied upon the flawed IID acreage estimates for determination of district water requirements. For example, for their calculations of ET demand in IID from 1989 through 2001, Jensen and Walter (2002) used the same annual acreage estimates published in the IID Annual Inventory of Areas Receiving Water. An exception to this approach was provided by the IID Water Study Team, a group of independent consultants working on behalf of IID. In 1998, the WST published a report summarizing the results from a ten-year study of IID's water use (WST, 1998). For this study, crops were divided into 31 categories spanning three primary groups; field, garden and permanent crops. In addition to the 31 crop categories listed, each of the three primary groups included a "miscellaneous" crop category representing the acres of minor crops in that group.

Annual acreages for permanent crops and perennial forages were determined using the average of all monthly values within the calendar year. Use of such averages is appropriate for permanent crops, such as citrus or dates, since the acreages of such crops do not vary much from month to month in any particular year. Moreover, although perennial forage acres can vary significantly as fields are brought into or out of production, use of the average planted acres for the calendar year takes this fluctuation into account. It should be noted that although the WST tallied annual acreage for forage crops (e.g., alfalfa, Sudangrass, and Bermuda grass), they calculated the annual ET for these crops by multiplying ET (derived from the crop coefficient-reference ETo method) by the acreage of each crop <u>in each month</u> before summing to annual totals. In dong so, a more accurate estimate of the annual ET demand for each crop was determined. It should be noted that the NRCE study team followed the same WST protocol during their assessment of IID water use (NRCE, 2002).

For annual crops that are planted in one calendar year and harvested in the following year, the WST assigned the crop acres to the <u>year of harvest</u>. In this way, 'double counting' and the error of assigning a peak-acreage to two subsequent years was eliminated. Comparison of IID's method (peak acreage method) with the WST approach (crop cycle method) for determining acreages of annual crops is illustrated in Figure 1 using onions and Figure 2 using broccoli. The bars in each chart represent the total crop acres compiled on a monthly basis for the years shown (acreage data obtained from IID Water Department Monthly Crop Acreage Reports). For each crop, the **red** bars indicate those acres (i.e., months) that would be selected using IID's method. This approach selects the peak acreage month during each calendar year. The **green** bars indicate the acres that would be selected following the WST protocol. This method selects the peak acreage month during each crop cycle. The **black** bar in Figure 2 indicates that the same acres (in this case, December,'93) would be selected using either method. In this instance, however, the IID method would assign these acres to 1993 while the WST method would assign the acres to 1994.

As indicated in Figures 1 and 2, IID's method exaggerates crop acreages and may miss entire crop cycles. For example, using the broccoli crops in Figure 2, the IID approach identifies February '92 (red bar) as the acreage value for 1992 and December '93 (black bar) as the acreage value for 1993. In doing so, IID omits the entire crop cycle which occurs between October '92 and April '93. Furthermore, it assigns January '94 (red bar) as the acreage value for 1994. Clearly, this is inappropriate since December '93 and January '94 are part of the same crop production cycle. As a result, the 1994-95 crop cycle is also overlooked in the acreage census.

For these reasons, the WST method for determination of annual crop acreage is preferred. As Figures 1 and 2 illustrate, the WST approach always selects the peak acres for annual crops from each production cycle (green (or black) bars). In this way, counting acres twice (i.e., double counting) from the same production cycle is avoided and an accurate estimate of the actual acres for each annual crop is ensured. This difference in determination of crop acreages between IID and that of the WST is significant since it directly impacts estimates of irrigation water requirements for any particular crop. These estimates rely, in part, upon the number of acres planted to each crop within the district service area. By overstating the annual acreages of some crops each year, IID implies a greater water need than actually exists.

General Crop Acreage Trends

An assessment of annual crop acreages is useful not only to determine total water requirements for each year, but also to evaluate planting trends that may be important when estimating future water diversions into the IID service area. Jensen and Walter (2002) reported that the total harvested area within the IID service area remained relatively constant between 1989 and 2001. During this time, the net irrigated area (not accounting for multiple cropping on the same field) averaged 460,800 acres, varying no more than 1.6% above or below this amount in any particular year. This amount of reported area, however, relied on the IID annual crop inventories which are overstated. Using the preferred WST methodology, the average net irrigated area was approximately 446,000. Allowing for multiple cropping, the total area of irrigated crops has fluctuated between 500,000 and 600,000 acres since 1960 (Figure 3).

As indicated in Figure 3, however, the total amount of cropped acres within the IID service area has trended downward over the past two decades, dropping below 500,000 acres during the 2001 and 2002 growing seasons. On average, about 9% less acreage was irrigated within IID from 1983 through 2001, as compared to the period of 1960 through 1982. This difference in total irrigated acres is attributable to a lesser amount of multiple cropping since 1983. Evidence for this is supported by a review of the Imperial County annual crop reports and the IID annual crop inventories. Historically, these data indicate an average of 123,000 acres were multiple-cropped between 1960 through 1982, while multiple cropping after 1982 averaged less than 71,000 acres per year.

Reported fallow or idle acreage also has trended lower during the past several years. Acres transitioned out of fallow or idle status are included in the cropping mix. Based on this consideration alone, an increase in irrigation water requirement may be implied since increases in cropped acres generally lead to increased water needs. But in fact, the total annual crop ET demand within the district has not varied much over the years (Jensen and Walter, 2002).

By definition, fallow acres are those acres not planted in any particular season. Consequently, these acres do not have an irrigation water requirement. Idle lands represent those acres that are not cropped during a portion of the season (i.e., remain idle), but may be cropped at other times. Typically, idle acres support multiple crops during the winter and spring months, or may be planted to field crops in the fall or winter months. Similar to fallow acres, idle acreage does not require special consideration for purposes of determining irrigation water needs. As these acres are brought into the crop mix, their irrigation water requirement is accounted for in the monthly inventory of crop acreage compiled by IID.

The significance of fallow/idle lands only pertains to assessment of the total cropped acres and/or total harvested area. As lands come out of production, they may remain idle for a few months or be fallowed for a longer time (e.g. one or more seasons). In this sense, the total cropped area is reduced. Conversely, as idle/fallow acres are brought back into production, the total cropped area is increased. This connection is depicted in Figure 4 which illustrates a generally inverse relationship between changes in total field and garden crop acreage versus acres of idle lands from 1989 through 2002. As such, idle/fallow lands do not require separate consideration for purposes of determining irrigation water requirements. Irrigation water requirements pertaining to these lands should only be assessed when they are planted to a crop.

Specific Crop Acreage Trends

In addition to the total cropped acres, the acreage assigned to individual crops and the planting trends of those crops is also important when considering irrigation water requirements. Multiple cropping (i.e., growing 2 or more crops on the same land in the same season) is implemented on a significant amount of acres within the IID service area, however, multiple cropping acreage has generally declined since the early 1980's (Figure 3). Jensen and Walter (2002) reported that total garden crop acreage decreased after reaching a peak in 1990 and has remained rather constant since then (garden crops are primarily used in multiple cropping schemes). However, using the WST method to compile acreage, total garden crop plantings in fact have trended <u>lower</u> since 1996 (with the exception of 1999) and averaged near 82,000 acres during the 2001 and 2002 crop seasons. On average, this represents a 17% decline in total garden crop plantings from the previous 5 years. Since 1996, acreage of lettuce (all types), onions, spring cantaloupes, ear corn, watermelons, tomatoes, potatoes, and mixed melons (including honeydews) has declined. These crops represented an average of 60% of the total garden crop acreage during this period. Plantings of carrots, fall cantaloupes, onion seed, broccoli, cabbage, and cauliflower have remained relatively steady.

Field crop plantings generally increased from 1989 through 1996, but have been in decline since then (Jensen and Walter, 2002). This downward trend is supported by acreage compilations derived using the WST protocol. Since 1996, the decrease in total field crop acreage has been attributable primarily to a reduction in wheat plantings. Alfalfa acreage increased during this same period although the increase in alfalfa plantings was not well correlated with the decline in wheat acreage. Other field crop planting reductions include Sudangrass and sugarbeets. Since 1996, plantings of these crops have declined an average of 44 and 28 percent for Sudangrass and sugarbeets, respectively.

The historical decline in several field and garden crops as described above strongly connotes a decrease in irrigation water requirement within IID. Although planted acres of Bermudagrass forage and seed crops have significantly increased since the early 1990's, the increased irrigation requirement of this crop has been largely offset by decreases in net plantings of other field and garden crops. This is also shown by Figure 3 in Allen (2003b). Accordingly, the relatively constant demand in total crop ET within the district during this same period also noted by Jensen and Walter (2002), and the declining demand by Allen, supports these observations.

Net Diversions and Crop Acreages

Changes in irrigation water requirement rely, in part, on total crop acreage plantings. Although the specific crop mix is also an important factor when considering water needs, significant changes in total cropped acres may be expected to influence the total crop water requirement within the district. Since 1960, net diversions of Colorado River water into the IID service area have fluctuated from a low 2.51 million acre-feet (MAF) in 1983 to a high of 3.16 MAF in 1996 (Figure 3). Although year-to-year variations have occurred, the general trend in net water diversions into the District has been upward, particularly since 1992. This trend seems unusual given the total acres of crops reported throughout this same time period. Net water diversions and the total acres of crops within IID from 1964 through 2002 are presented in Figure 5. The general trend in net water diversions has been upward while that of total acres of crops has been downward. This tendency is particularly evident since the early '80's and in more recent years. A linear regression analysis of net water diversions on total acres of crops over the entire 39-year period indicated no correlation between these variables ($r^2 = 0.01$). This indicates that historical increases and decreases in net diversions of Colorado River water into the IID service area cannot be explained by changes in total cropped acres.

Crop Yields

Crops subjected to stress due to a lack of water, poor soil, inadequate nutrition, pest pressure, or other environmental constraints, will generally produce yields that are less than optimum. In the case of inadequate water, increases in irrigation water application will generally contribute to increases in crop yield. This relationship is only valid, however, to an upper limit near the ET demand of the region (see subsequent discussion on ET and crop yield).

IID has concluded, through assessment and reporting by independent consultants, that crop yields throughout the district are in decline or generally are lower than optimum (NRCE, 2002). This conclusion is based on the presumption that the medium and heavy cracking soils, which IID maintains are prevalent within its district, are contributing to reduced water infiltration and increased soil salinization. IID asserts that greater diversions of Colorado River water are necessary to reverse this trend, i.e., to decrease soil salinity and thereby increase crop yields.

Yet, as alluded to above, IID's assertion and conclusions are not based on any actual data showing that that crop yields have decreased. Furthermore, based on my assessment of crop yield trends within Imperial County and elsewhere, IID's claim that crop yields are declining cannot be supported. Yield data for Imperial County is considered representative of IID since harvested acreage within IID comprises approximately 90 percent (or more) of the total cropped acres throughout the county. The crops I selected for comparison were those representing the highest acreages and/or valuations within Imperial County and included field, garden, and permanent plantings. In addition, crop yields within various counties throughout California were obtained from the California Agricultural Statistics Service representing the period from 1980 through 2001. Crop yields for Maricopa and Yuma counties representing the period from 1984 through 2002 were obtained from the Arizona Agricultural Statistics Service.

The primary statistic used to compare the magnitude of crop yield variation among different counties was the coefficient of variation (CV). The CV expresses the standard deviation (s) of annual crop yields within a particular county as a percentage of the average crop yield (x) for that county (CV = (s/x) 100). The CV is useful for comparing the magnitude of variation in crop yield between counties. For example, a large CV reflects greater variation in crop yield over the time period evaluated.

Evaluations of crop yield trends were considered using three separate approaches. The first approach involved an assessment of yield trends within Imperial County alone. The second approach considered crop yields in Imperial County relative to those in counties elsewhere in California. Finally, a third approach was to contrast crop yield trends in Imperial County to those of the same crops in other 'desert-like' production regions. The other regions included the counties of Riverside and San Bernardino in California, as well as Maricopa and Yuma counties in Arizona. Crop yield trends were evaluated both statistically and qualitatively.

Yields for the various crops and counties considered are presented in Tables 1 and 2 for the years 1980 through 2001. Charts showing the yield trends in field, garden, and fruit crops within Imperial County are also attached (Figures 6 through 8). From 1980 through 2001, crops exhibiting notable increases in yield within Imperial County included sugarbeets, wheat, broccoli, cantaloupes, and head lettuce. Fresh market onion and leaf lettuce yields also have increased, albeit to a lesser degree. Yields of alfalfa hay, cotton, Sudangrass hay, and carrots have remained relatively unchanged.

Yield trends among the fruit crops have exhibited more variation across years. This is not unusual since yields tend toward alternate-bearing habits in many perennials (i.e. high crop in one year followed by a low crop the next, etc.). In addition, citrus (which represents most of the permanent crop plantings in Imperial County) has been periodically subjected to freeze which has reduced production in some years. In general, yields of citrus crops have tended to vary within a reasonable range with some large production swings in certain years. An exception is grapefruit production which has tended to increase during the 22-year period, particularly since 1992. In addition, date yields have increased from less than 2.0 tons per acre in the early 1980's to a relatively steady 3.0 to 4.0 tons per acre since 1985.

A review of the yield trends in Table 1 indicates that CV's for crop yields in Imperial County were similar to those of other California counties for the following crops: alfalfa, cotton, Sudangrass hay, wheat, onions, carrots, leaf lettuce, grapefruit and lemons. Yield variations (i.e., higher CV's) were generally greater in those crops where yields have shown notable <u>increases</u>. These included sugarbeets, broccoli, cantaloupes, and head lettuce. It should also be noted that yields of certain garden crops such as cantaloupes and lettuce may vary widely from year to year due to market forces alone. That is, the actual production reported is often dependent upon commodity prices during the harvest period with higher prices typically leading toward higher production (i.e., more extensive harvesting). Among permanent crops, yield variations (CV's) were relatively higher (compared to those of field and garden crops) for all the counties considered. As indicated previously, this can be attributed to the higher degree of year-to-year production variation associated with these crops.

Among the desert counties alone, the CV's for crop yields were similar for alfalfa, Sudangrass hay, wheat, onions and head lettuce (Table 2). CV's in Imperial County were notably lower for broccoli, carrots, and leaf lettuce indicating good yield stability among these crops when compared to counties with similar climate regimes. The CV for cotton yields in Imperial County was lower than that in Riverside County, but somewhat higher compared to those in Arizona. Despite these variations in year-to-year yields, however, average cotton yields were essentially the same among all counties over the 18-year period. Yield variations among the citrus crops were similar to those observed among the California counties shown in Table 1. Citrus crop yield CV's were generally much higher than those for field and garden crops in all counties. Again, these higher yield variations are mainly attributable to relatively large production spikes that occur with these crops in some years (due to freezes or unusually high pest pressure). Lower production levels associated with aging orchards as well as newer plantings also influence county average yield estimates for perennials.

The presumption that increased water diversions from the Colorado River have been necessary to support crop yields within the IID service area is specious. The crop yield trends discussed above and shown in Tables 1 and 2 clearly indicate that deficient or declining yields have not occurred in Imperial County (and therefore IID) during the past 22 years. Indeed, yields have generally remained steady or trended upward for most of the primary crops. Increasing yield trends in Imperial County were indicated by larger crop yield CV's as compared to those for the same crops grown in other regions throughout California and Arizona. It is also important to note that, in addition to soil and water factors, crop yield responses are influenced by plant genotype, pest pressures, environment, and cultural practices. Based on these considerations and the analysis above, there is no evidence to support the contention that additional irrigation water is needed to improve or sustain crop productivity within the IID service area.

Evapotranspiration (ET) and Crop Yield

In general, yield is directly related to the cumulative seasonal ET of a crop. As ET increases, crop yield also increases until maximum ET is reached. At this point, yield is also at a maximum. When crop ET is not met, plant growth, crop yield, or crop quality declines. Thus, crop ET must be maintained at its maximum rate to optimize yield for most crops.

A relative lack of rainfall in recent years has raised concerns within IID that ET rates in the district service area have risen, thereby increasing the need for additional irrigation water. This assertion, however, is based on limited climatic information evaluated over specific time periods. Variations in ET demand over short time periods are normal and probable when comparing similar periods between years. This is due to short-term changes in weather conditions. The impact on annual ET is always much less. As such, the presumption that water requirements are increasing in IID due to changes in ET demand is incorrect. To better evaluate the pattern of evapotranspiration demand in IID, annual reference ET (ETo) values were compiled for the period 1984 through 2002 using data obtained from the California Irrigation Management Information System ("CIMIS"). The annual ETo values were collected from the Calipatria, Seeley, and Meloland stations maintained by CIMIS and located within IID's service area[1]. The ETo values were averaged based on an area weighting of the three stations and plotted against the weighted long-term historic 3-station average as shown in Figure 9.

Year-to-year fluctuations in ET demand are normal; however, when evaluated over several years, the average variances in any particular region tend to remain within a nominal range. For the 19-year period evaluated, the weighted average annual ETo for the three CIMIS stations was 75.3 inches (standard deviation = 3.9; standard error of the average = +/- 0.9). Although the ETo demand has increased since the 2000 crop season (about 3%), the increase is relatively small and well within normal fluctuations for the region. Furthermore, a regression analysis of annual ETo vs. annual precipitation within IID from 1984 through 2002 showed no correlation ($r^2 = 0.05$).

It has also been suggested that increases in crop yield lead to proportional increases in crop ET demand (and thereby increase crop water requirements). This notion is based on the perception that crop yield-ET relationships are always linear. This presumption, however, fails to recognize fundamental physical principles governing the rate of ET and accumulation of plant biomass. ET is an energy-consuming process that is limited by solar radiation, air temperature and humidity. Large amounts of energy are

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[1] ETo values were collected directly from CIMIS and corrected for errors due to faulty sensor readings or drift. Seeley and Meloland stations were established in 1987 and 1989, respectively.

required to convert liquid water in the soil and plants into vapor that escapes into the atmosphere. Accumulation of plant biomass (and subsequent yield) relies on the amount of photosynthetically active radiation (PAR) absorbed by the crop. Both ET and absorbed PAR are driven by solar radiation, temperature and humidity. These environmental factors cannot and do not change with crop yield.

Increases in plant biomass may lead to increases in ET, however, this is only true when the plant leaf canopy is less than full cover (not fully shading the ground). As leaf area increases it absorbs more solar radiation, however, due to the energy constraint on maximum ET, increases in plant biomass produce sharply diminishing impacts on ET as the developing leaf canopy more effectively shades the ground and absorbs all available solar radiation. In the case of alfalfa hay, for example, the ET rate attains a maximum energy-limited value when the plant reaches a height of about 14 inches. Beyond this height, increases in plant biomass or leaf canopy have no effect on ET demand since the ground area is already completely shaded.

The literature suggests that crop leaf area index (the amount of leaf area per unit ground area) has historically remained essentially unchanged for nearly all crop types grown in Imperial Valley (Etcheverry and Harding, 1933). What has changed is the size and amount of fruit and grain associated with the same amount of biomass or leaf canopy. This has resulted in a proportionate increase in yield per unit of land area. This trend has been a part of the "green revolution" that has increased crop production more than three-fold on a world scale since the 1920's.

FAO Irrigation and Drainage Paper Number 33 (Doorenbos and Kassam, 1979) has been referenced by IID to support the notion that ET increases linearly with yield. The linear relationship between ET and yield, however, holds only for those conditions in which ET is limited by environmental constraints such as soil water deficits, poor soil aeration, deficient nutrient supply, pest infestation, severe soil salinity, or poor cultural practices. Paper 33 does not support the view of linearity or proportionality between ET and yield when the yield increases are due to improved fertility or genetics. Using the data presented in the NRCE report (NRCE, 2002), a comparison of the net irrigation requirement calculated for "standard ideal conditions" against the actual amount of irrigation water consumption on IID lands reveals that crop ET in the IID water service area is at a practical maximum for the specific cropping pattern. Consequently, crops within the IID service area are not subjected to the type of environmental stresses identified in FAO Paper 33 in which a linear relationship between yield and ET would be expected to occur.

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Attachment: CV
Tables 1 and 2
Figures 1 through 9

17-Jan-03

TABLE 1. CROP YIELD TRENDS WITHIN VARIOUS COUNTIES IN CALIFORNIA

Source: California Agricultural Statistics Service

Units: Tons/Acre

*Sorted by CV

Crop	County	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Avg	S[1]	CV[2]
																										%
Alfalfa Hay	Santa Barbara	7.6	8.2	9.2	8.8	7.4	8.1	7.8	6.4	6.6	7.3	7.0	7.6	8.1	8.2	7.8	8.0	7.1	8.7	6.9	6.7	7.4	7.4	7.6	0.74	9.7
	San Bernardino	7.4	8.3	7.3	7.6	7.2	7.9	8.0	7.2	7.0	7.2	7.3	7.6	8.3	8.5	7.8	8.5	8.3	8.2	9.5	8.1	8.3	9.1	7.8	0.73	9.3
	Fresno	7.2	7.2	7.7	8.0	9.0	8.8	8.8	8.8	9.0	8.9	9.0	7.4	7.7	8.6	9.1	7.7	7.4	8.2	7.0	7.6	7.6	7.6	8.1	0.72	8.8
	Riverside	7.1	7.3	7.8	8.1	9.2	8.7	8.9	8.3	8.0	8.0	8.5	8.0	8.7	9.2	8.7	8.7	9.5	8.9	9.5	8.7	8.1	8.9	8.5	0.65	7.6
	Imperial	8.3	8.1	8.7	8.5	8.3	8.3	8.2	8.8	8.7	9.8	9.7	8.5	7.9	8.1	7.9	7.9	7.8	7.5	7.7	8.0	8.1	8.1	8.3	0.50	6.2
	Tulare	8.2	7.6	7.8	8.2	8.5	7.7	8.4	8.3	8.6	8.6	9.0	8.0	8.0	8.1	8.9	7.1	9.1	9.3	7.5	8.7	8.4	9.0	8.3	0.56	7.0
Cotton (Lint - Upland)	Riverside	0.58	0.64	0.59	0.59	0.64	0.70	0.64	0.71	0.52	0.54	0.42	0.55	0.52	0.70	0.74	0.50	0.55	0.83	0.63	0.74	0.92	0.77	0.6	0.12	18.5
	Imperial	0.71	0.56	0.60	0.70	0.62	0.68	0.59	0.60	0.50	0.58	0.51	0.45	0.53	0.67	0.70	0.69	0.69	0.88	0.50	0.72	0.77	0.71	0.6	0.10	15.3
	Kern	0.50	0.57	0.56	0.52	0.50	0.66	0.60	0.65	0.52	0.59	0.60	0.62	0.70	0.67	0.63	0.49	0.60	0.65	0.43	0.68	0.79	0.67	0.6	0.08	14.0
	Kings	0.49	0.54	0.58	0.51	0.50	0.54	0.56	0.61	0.46	0.59	0.55	0.59	0.73	0.67	0.58	0.47	0.49	0.50	0.47	0.62	0.65	0.67	0.6	0.07	13.2
	Fresno	0.54	0.65	0.56	0.54	0.56	0.68	0.65	0.74	0.60	0.72	0.68	0.66	0.79	0.75	0.75	0.62	0.70	0.65	0.52	0.67	0.73	0.76	0.7	0.08	12.1
Sudangrass Hay	Merced	na	na	na	na	na	na	na	na	4.0	3.6	2.6	3.4	4.0	7.7	4.2	3.1	2.9	3.0	3.7	3.8	5.5	4.6	4.0	1.29	32.3
	San Bernardino	na	na	na	na	na	na	na	na	na	na	na	na	na	na	2.7	3.4	3.8	4.1	4.0	3.0	4.0	2.5	3.4	0.64	18.5
	Imperial	5.0	5.5	5.0	4.6	4.3	4.7	5.0	6.8	5.5	4.0	8.0	5.0	6.5	5.5	6.6	6.5	6.4	5.6	4.9	4.9	4.9	5.3	5.5	0.96	17.2
	Riverside	na	na	na	na	na	na	na	na	5.5	5.9	6.9	5.5	6.3	7.5	6.8	7.9	7.5	6.2	5.6	4.6	4.7	5.5	6.2	1.04	16.8
Sugar Beets	Imperial	26.9	26.3	22.5	22.0	24.9	21.3	25.4	26.6	24.2	26.4	28.5	28.2	30.1	30.2	32.3	32.1	34.5	34.6	36.1	40.7	38.6	41.6	29.9	5.32	15.7
	Fresno	28.3	27.3	30.3	26.4	27.2	30.0	26.3	31.5	26.1	30.0	25.6	25.5	26.3	29.0	28.6	28.9	33.5	31.6	29.1	33.2	35.8	39.0	29.5	3.49	11.8
	Kern	26.6	25.8	25.6	25.0	28.1	23.5	29.5	28.6	29.0	27.1	27.1	24.2	29.1	34.3	29.2	31.7	28.0	31.7	32.0	27.2	32.6	33.2	28.6	3.00	10.5
	Tulare	31.3	32.4	27.7	25.1	26.4	25.0	27.3	33.5	30.7	33.1	28.3	26.9	27.0	27.0	27.3	35.2	27.0	30.2	29.0	28.4	27.7	32.5	29.1	2.88	9.9
Wheat	Riverside	2.2	2.5	2.5	2.2	1.9	1.5	2.3	1.7	1.4	1.6	1.2	1.2	1.4	1.6	1.8	1.8	1.6	0.8	1.8	0.0	2.5	0.9	1.6	0.61	36.9
	Tulare	2.8	2.3	2.1	1.9	2.7	2.4	1.9	2.3	2.9	2.7	2.7	2.8	2.5	2.6	2.4	2.5	2.5	2.6	1.8	2.3	2.9	2.3	2.5	0.31	12.8
	Fresno	2.8	2.4	2.3	2.4	2.9	3.1	2.7	2.2	2.8	3.2	2.9	2.9	3.3	3.1	3.1	2.3	2.5	2.7	2.3	2.7	3.0	3.1	2.7	0.33	11.9
	Kern	2.3	2.4	2.4	2.6	2.8	2.7	2.6	2.7	2.8	2.9	3.0	2.6	2.5	2.4	2.8	2.6	2.7	2.7	2.4	3.1	2.8	3.1	2.7	0.22	8.2
	Imperial	2.3	2.7	2.3	3.0	2.9	3.3	2.6	2.6	2.9	2.7	2.9	2.5	2.3	2.3	2.9	2.3	3.0	3.2	3.3	3.1	3.2	3.3	2.8	0.22	7.7
Onions (fresh mkt)	Monterey	15.2	14.7	13.8	18.6	19.9	18.2	20.6	18.3	23.7	23.6	15.4	24.2	25.3	27.8	29.1	19.5	23.3	24.3	22.3	21.5	22.2	21.9	21.1	4.13	19.6
	Riverside	15.9	19.0	18.2	17.7	17.6	16.2	15.1	19.8	19.1	17.0	22.1	16.6	20.4	24.5	23.2	21.4	20.3	26.3	25.2	22.7	20.1	25.5	20.2	3.33	16.5
	Imperial	17.6	16.5	17.5	12.9	15.8	15.7	21.9	21.1	20.4	19.3	20.5	19.2	18.3	17.4	17.3	22.1	15.6	20.9	23.7	20.7	19.5	17.5	18.5	2.59	14.5
	Kern	18.1	15.8	18.3	14.5	19.6	15.9	19.9	19.3	19.1	20.2	22.0	20.2	20.9	19.4	19.5	19.2	19.2	20.6	18.3	20.7	21.8	19.4	19.2	1.85	9.6
	Fresno	20.6	16.5	20.7	17.7	19.6	16.3	17.8	18.0	18.3	18.3	19.0	19.5	18.6	20.0	20.3	19.4	20.8	18.6	16.6	20.4	21.1	20.2	19.0	1.45	7.7
Broccoli (fresh mkt) (Unspecified in some yrs)	Riverside	3.4	4.3	8.4	3.3	4.3	5.1	4.9	4.6	5.2	4.9	4.7	4.5	6.2	6.0	7.0	6.3	7.2	7.9	6.9	7.3	7.2	6.4	5.7	1.44	25.2
	Imperial	3.2	3.0	3.5	3.6	5.1	8.9	3.4	5.6	5.7	5.0	5.3	6.5	5.0	5.4	6.3	5.0	5.0	5.8	7.0	5.5	5.3	5.5	5.5	1.38	25.0
	Monterey	3.7	4.4	4.7	4.8	4.6	6.0	6.5	6.3	6.2	6.5	5.8	6.4	7.6	7.4	6.2	6.0	5.8	5.9	5.3	7.3	7.2	6.9	6.0	1.03	17.2
	Santa Barbara	4.3	4.4	4.7	5.3	5.5	6.8	7.5	7.6	6.6	7.1	6.8	7.3	7.4	7.7	7.4	7.1	7.1	7.0	7.2	7.1	6.8	6.7	6.6	1.05	15.9
Carrots (fresh mkt) (Unspecified in some yrs)	Kern	11.2	12.9	13.7	10.6	10.9	23.1	35.0	30.0	27.0	25.0	28.5	17.1	16.7	16.7	9.9	30.8	31.1	na	na	na	na	na	20.6	8.60	41.8
	Riverside	6.6	13.1	11.9	10.9	19.9	14.2	14.2	13.7	10.7	15.7	10.4	14.8	14.2	17.4	17.8	20.7	16.8	21.6	18.1	24.6	22.7	17.4	15.8	4.44	28.1
	Monterey	18.4	18.0	17.6	13.7	16.1	17.0	18.7	14.6	19.8	20.5	20.1	21.3	24.3	23.1	24.7	6.0	8.4	10.6	12.2	21.8	21.0	20.8	17.8	4.97	28.0
	Imperial	13.0	19.1	21.8	20.8	23.4	19.0	25.0	25.9	24.3	23.3	19.7	18.2	20.4	23.9	17.9	20.5	17.7	19.4	19.9	20.8	19.5	20.0	20.9	2.47	11.9
Cantaloupes (Unspecified)	Imperial	5.4	5.1	8.2	6.2	5.7	5.3	5.7	8.4	5.7	9.1	4.1	3.3	9.9	12.3	8.4	7.4	8.3	8.0	10.3	7.8	8.1	9.5	7.4	2.20	29.9
	Kern	8.4	7.7	4.4	8.8	10.7	9.4	14.1	9.0	10.8	11.1	9.3	7.3	12.6	11.9	13.7	12.6	15.8	15.6	16.7	11.2	14.7	14.3	11.4	3.17	27.9
	Riverside	9.9	2.9	17.0	7.0	9.4	8.7	7.7	6.9	9.7	9.5	7.7	8.4	10.2	9.1	9.4	10.5	10.5	9.3	11.6	10.8	10.9	10.1	9.4	2.51	26.7
	Fresno	9.1	8.3	10.3	9.8	10.0	10.1	10.4	9.7	6.8	10.5	9.5	9.7	9.0	7.8	10.2	10.8	12.7	11.9	13.1	12.6	13.2	13.9	10.4	1.83	17.5
	Merced	9.9	9.8	8.0	9.1	8.4	8.7	8.9	9.1	9.4	6.7	7.7	6.5	7.2	7.2	8.6	9.3	9.8	9.9	9.4	9.8	10.7	10.3	8.8	1.18	13.4
Lettuce, Head (Unspecified 1980 - 1983)	Imperial	7.9	10.4	6.6	10.8	13.4	12.7	13.8	11.6	11.8	9.7	9.8	11.2	9.9	11.6	8.6	12.3	10.8	12.2	13.0	14.3	15.3	17.0	11.4	2.36	20.5
	Santa Barbara	16.8	17.7	17.3	15.1	8.37	7.1	19.0	17.7	17.6	18.7	18.3	18.8	17.5	19.35	16.6	15.6	17.0	18.7	15.6	15.0	15.7	19.8	16.5	3.17	19.2
	Monterey	15.1	16.3	16.2	16.7	16.7	16.6	18.1	18.4	20.8	20.6	20.3	19.2	18.9	19.0	18.9	11.5	13.7	14.1	14.4	22.5	24.2	22.3	17.9	3.16	17.6
	Riverside	13.4	16.3	10.8	14.0	13.2	15.1	16.4	13.7	12.1	17.5	15.2	9.6	13.8	14.9	10.0	13.0	12.7	10.7	11.2	12.0	11.8	10.0	13.1	2.22	17.0
	Fresno	14.9	16.6	17.6	18.9	18.1	16.5	17.2	14.7	14.7	14.8	16.5	15.0	15.9	17.6	17.7	17.6	18.0	17.4	18.9	16.2	17.7	16.9	16.8	1.34	8.0
Lettuce, Leaf	Riverside	na	na	na	na	74.6	7.8	6.5	8.3	6.3	6.9	7.4	6.0	5.9	8.8	8.5	9.8	8.3	9.0	9.9	9.5	9.7	9.3	11.8	15.72	133.2
	Santa Barbara	na	na	na	na	16.1	17.0	8.0	9.4	9.1	10.6	9.7	9.6	9.7	11.4	14.2	11.1	9.9	10.4	10.5	10.7	11.8	10.8	11.1	2.37	21.3
	Imperial	na	na	na	na	na	na	na	14.0	10.3	3.9	10.6	12.2	11.7	12.8	14.4	14.8	12.9	14.9	16.3	14.6	15.7	16.1	13.4	2.24	16.8
	Monterey	na	na	na	na	12.2	15.1	12.9	12.1	12.5	14.3	10.3	10.0	10.4	9.9	10.4	10.3	10.5	10.6	10.6	10.8	11.3	10.0	11.3	1.53	13.5

17-Jan-03

TABLE 1. CROP YIELD TRENDS WITHIN VARIOUS COUNTIES IN CALIFORNIA

Source: California Agricultural Statistics Service

Units: Tons/Acre

Crop	County	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	*Sorted by CV Avg	S[1]	CV[2]
Oranges (Navels)	Imperial	4.9	4.4	3.4	6.9	8.0	14.1	7.2	7.5	6.1	7.6	11.4	19.9	8.3	7.9	6.1	3.9	3.3	1.0	3.5	5.7	3.6	2.6	6.7	4.22	62.8
(Unspecified in some yrs)	Riverside	7.4	5.7	6.5	7.1	8.3	7.6	9.1	6.7	11.1	11.6	17.9	10.3	18.6	11.8	11.9	11.6	12.5	12.8	17.8	4.4	5.6	12.5	10.4	4.04	38.9
	Ventura	14.3	13.7	8.0	17.4	7.0	10.0	8.6	10.8	11.9	10.3	17.2	10.7	15.2	7.8	18.6	12.7	11.1	15.6	13.5	17.6	12.0	10.5	12.5	3.41	27.3
	Tulare	13.4	14.7	9.7	16.1	12.5	8.8	12.3	12.1	11.9	12.4	16.4	4.9	11.0	12.3	12.2	13.5	12.5	12.1	12.8	5.4	16.7	17.1	12.3	3.13	25.5
	San Bernardino	5.3	6.8	5.1	11.2	9.6	9.5	9.0	13.0	10.9	10.9	12.6	8.1	15.3	12.3	11.9	11.5	11.4	11.3	12.5	11.2	10.6	12.4	10.6	2.48	23.5
Tangerines	Imperial	4.0	3.0	5.8	9.0	5.1	6.1	7.7	7.3	8.7	7.5	13.0	10.1	5.0	11.0	7.8	9.8	5.9	5.1	4.2	10.0	3.5	4.4	7.0	2.56	37.3
	Tulare	6.5	8.9	7.9	9.4	7.4	8.2	6.1	7.5	6.1	8.1	9.5	4.0	9.1	8.5	10.3	10.6	13.1	10.3	6.2	5.0	9.8	6.9	8.2	2.09	25.7
	Riverside	9.2	9.9	7.1	7.9	8.0	7.9	8.9	7.7	11.5	10.1	11.7	9.7	9.0	13.7	12.2	11.8	10.4	8.2	6.2	6.3	7.3	8.2	9.2	2.01	21.8
	San Diego	15.4	11.6	13.5	14.0	12.0	9.6	11.6	na	na	na	na	na	na	na	na	na	na	na	na	17.8	14.1	8.8	12.8	2.70	21.0
Grapefruit	San Diego	10.2	14.6	8.9	10.8	14.5	12.2	11.2	12.2	13.1	14.4	16.1	15.8	29.1	31.6	21.6	21.0	16.0	18.6	16.0	16.7	16.6	11.6	16.0	5.67	35.3
	Tulare	10.5	11.9	10.1	5.8	4.9	8.1	7.3	14.5	11.8	13.0	13.8	3.4	16.0	9.9	8.1	12.6	18.0	13.1	8.5	12.5	12.3	12.7	10.9	3.61	33.3
	Imperial	4.0	11.4	9.3	13.5	10.8	10.8	10.4	9.7	16.0	6.3	9.9	10.5	14.4	13.2	13.5	14.5	7.6	14.6	12.2	15.5	13.1	9.5	11.0	2.89	26.5
	San Bernardino	10.2	10.6	7.5	8.8	13.5	16.0	14.7	17.4	16.3	17.5	16.8	8.9	17.5	12.7	12.0	10.0	10.7	10.2	10.2	10.2	10.6	10.5	12.4	3.23	26.0
	Riverside	8.9	8.4	13.1	11.6	10.4	10.8	10.5	9.7	14.7	9.6	16.0	15.5	17.3	20.1	12.6	15.5	16.1	14.6	17.3	14.5	15.5	16.2	13.6	3.21	23.6
Lemons	San Bernardino	13.3	18.8	22.4	40.4	35.8	46.7	27.2	17.2	7.4	11.3	11.3	1.9	3.5	7.7	9.6	8.3	7.9	8.0	7.9	15.0	3.3	4.8	15.0	12.37	82.6
	Tulare	12.7	16.2	12.6	12.4	10.7	12.8	11.6	14.4	13.1	10.1	9.7	8.7	0.3	5.8	9.7	13.5	12.7	19.5	14.0	9.5	9.1	13.1	11.5	3.80	33.1
	Riverside	6.0	6.3	5.4	7.0	10.5	8.4	6.0	6.4	9.6	11.7	12.4	12.4	13.8	15.1	15.0	11.5	12.8	11.5	14.0	12.3	15.0	16.6	10.9	3.50	32.1
	Imperial	5.4	10.1	5.4	9.0	5.2	7.9	7.3	4.6	5.3	5.6	6.5	8.6	9.8	7.5	11.7	9.7	9.1	7.0	8.0	5.7	5.1	5.7	7.4	1.92	26.0
	San Diego	12.7	17.4	19.0	23.0	15.0	10.2	11.3	8.9	13.2	14.1	14.6	14.7	21.6	21.5	19.9	20.7	19.8	20.0	19.4	19.6	19.1	13.0	16.8	4.10	24.5
Dates	Imperial	1.9	2.1	2.0	1.4	2.3	3.0	3.3	3.2	3.9	4.2	3.1	3.3	4.7	4.1	3.3	4.1	3.5	3.3	3.0	3.1	2.8	3.2	3.2	0.84	26.5
	Riverside	5.7	6.0	5.4	5.3	4.4	3.8	4.4	3.8	3.9	4.3	4.2	4.3	4.7	6.0	6.8	4.5	5.7	5.6	7.1	4.9	3.1	4.5	4.9	1.00	20.4

1 Standard deviation of the mean
2 Coefficient of variation (= (S / Avg)100)
3 Standard error of the mean (= S / (Square Root of n), where n = # of samples)

TABLE 2. CROP YIELD TRENDS WITHIN DESERT COUNTIES IN CALIFORNIA AND ARIZONA.

Source: California Agricultural Statistics Service; Arizona Agricultrual Statistics Service

Units: Tons/Acre — *Sorted by CV

Crop	County	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Avg	S[1]	CV[2] %
Alfalfa Hay	San Bernardino	7.2	7.9	8.0	7.2	7.0	7.2	7.3	7.6	8.3	8.5	7.8	8.5	8.3	8.2	9.5	8.1	8.3	9.1	8.0	0.69	8.6
	Imperial	8.5	8.9	8.2	8.8	8.7	9.8	9.7	8.5	7.9	8.1	7.9	7.9	7.6	7.5	7.7	8.0	8.1	8.1	8.3	0.65	7.8
	Yuma	8.2	7.9	8.8	9.6	9.5	8.6	9.4	8.7	8.8	8.1	8.6	9.0	8.1	9.0	7.7	8.3	8.7	8.3	8.6	0.54	6.3
	Riverside	9.2	8.7	8.9	8.3	8.0	8.0	8.5	8.0	8.7	9.2	8.7	8.7	9.5	8.9	9.5	8.7	8.1	8.9	8.7	0.49	5.6
	Maricopa	7.7	7.8	7.8	8.1	8.1	7.6	7.3	8.0	7.2	7.3	7.5	8.5	8.4	8.4	8.0	8.2	8.5	8.1	7.9	0.42	5.3
Cotton (Lint - Upland)	Riverside	0.64	0.70	0.64	0.71	0.52	0.54	0.42	0.55	0.52	0.70	0.74	0.50	0.55	0.83	0.63	0.74	0.92	0.77	0.6	0.13	20.0
	Imperial	0.52	0.58	0.59	0.60	0.50	0.58	0.51	0.45	0.53	0.67	0.70	0.69	0.59	0.83	0.60	0.72	0.77	0.71	0.6	0.11	16.7
	Yuma	0.60	na	0.67	0.74	0.63	0.68	0.59	0.70	0.54	0.67	0.70	0.63	0.64	0.73	0.49	0.63	0.69	0.56	0.6	0.07	10.6
	Maricopa	0.65	0.65	0.67	0.73	0.59	0.67	0.58	0.61	0.52	0.65	0.62	0.54	0.62	0.64	0.61	0.64	0.68	0.59	0.6	0.05	8.1
Sudangrass Hay	San Bernardino	na	na	na	na	na	na	na	na	na	na	2.7	3.4	3.8	4.1	4.0	3.0	4.0	2.5	3.4	0.64	18.5
	Imperial	4.8	4.7	5.0	6.8	5.5	4.0	8.0	5.0	6.5	6.5	6.6	6.5	6.4	5.6	4.9	4.9	4.9	5.3	5.7	1.02	18.1
	Riverside	na	na	na	na	5.5	5.9	6.9	5.5	6.3	7.5	6.8	7.9	7.5	6.2	5.6	4.6	4.7	5.5	6.2	1.04	16.8
	Maricopa	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Sugar Beets	Imperial	24.9	21.3	25.4	25.6	24.2	25.4	28.6	28.2	30.1	30.2	32.3	32.1	34.5	34.6	36.1	40.7	33.6	41.6	30.9	5.85	18.9
	Maricopa	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Wheat	Riverside	1.9	1.5	2.3	1.7	1.4	1.6	1.2	1.2	1.4	1.6	1.8	1.8	1.6	0.8	1.8	0.0	2.5	0.9	1.5	0.56	37.4
	Imperial	2.9	2.8	2.6	2.6	2.9	2.7	2.9	2.5	2.9	2.8	2.9	2.8	3.0	3.2	3.3	3.1	3.2	3.3	2.9	0.24	8.4
Durum	Yuma	3.0	2.7	2.8	2.8	2.9	2.9	3.1	3.0	2.8	2.7	3.0	3.1	3.0	2.9	3.5	2.9	3.1	2.9	2.9	0.19	6.5
Durum	Maricopa	3.0	2.8	2.8	2.8	2.8	2.9	2.9	2.9	2.6	2.8	2.8	2.8	2.8	2.8	3.2	3.0	2.9	2.7	2.8	0.14	5.1
Onions (fresh mkt)	Riverside	17.6	16.2	15.1	19.8	19.1	17.0	22.1	16.6	20.4	24.5	23.2	21.4	20.3	26.3	25.2	22.7	20.1	25.5	20.7	3.41	16.5
	Maricopa	20.0	24.0	27.5	22.7	18.8	21.8	24.9	27.1	18.6	28.5	23.2	28.7	21.5	17.8	28.9	25.5	22.3	22.7	23.6	3.57	15.1
	Imperial	15.8	15.7	21.9	21.1	20.4	15.3	20.5	19.2	18.3	17.4	17.3	22.1	15.6	20.9	23.7	20.7	19.5	17.5	19.0	2.54	13.3
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Broccoli (fresh mkt) (Unspecified in some yrs)	Maricopa	3.4	4.4	3.3	4.2	3.5	4.1	6.5	4.1	4.2	3.6	4.9	6.3	5.0	5.0	5.0	8.9	9.1	9.2	5.2	1.96	37.5
	Yuma	na	4.9	5.5	4.9	5.0	5.6	5.4	5.0	5.5	4.1	5.7	5.3	4.7	6.8	7.0	10.7	10.5	10.4	6.3	2.14	34.1
	Imperial	5.1	8.9	5.4	5.6	5.7	5.0	5.8	6.5	5.0	6.4	6.2	6.3	5.0	6.8	7.0	5.6	5.3	6.5	6.0	0.97	16.2
Carrots (fresh mkt) (Unspecified in some yrs)	Maricopa	6.6	8.3	8.3	10.0	6.3	8.5	6.5	8.0	7.2	9.8	6.8	13.8	13.6	13.3	12.5	12.5	13.5	na	9.7	2.84	29.2
	Imperial	23.4	19.0	25.0	25.9	24.3	23.8	19.7	18.2	20.4	23.9	17.9	20.5	17.7	19.4	19.9	20.8	19.5	20.0	21.1	2.61	12.4
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Cantaloupes (Unspecified in CA)	Yuma (spring)	16.4	19.4	23.8	18.9	21.6	12.5	14.6	13.3	19.8	14.6	38.4	39.3	42.5	49.6	41.9	37.5	31.3	35.9	27.3	12.11	44.4
	Imperial	5.7	5.3	5.7	8.4	5.7	9.1	4.1	3.3	9.9	12.3	8.4	7.4	3.3	8.0	10.3	7.6	8.1	9.5	7.6	2.29	30.1
	Maricopa (spring)	8.3	8.8	9.2	8.7	8.6	8.5	6.9	9.1	10.7	14.1	12.4	14.3	14.6	16.0	12.2	13.5	11.3	13.0	11.1	2.72	24.5
	Riverside	9.4	8.7	7.7	6.9	9.7	9.5	7.7	8.4	10.2	9.1	9.4	10.5	10.5	9.3	11.6	10.8	10.9	10.1	9.5	1.24	13.1
Lettuce, Head	Imperial	13.4	12.7	10.8	11.6	11.8	9.7	9.8	11.2	9.9	11.6	8.6	12.3	10.8	12.2	13.0	14.3	15.3	17.0	12.0	2.09	17.5
	Riverside	13.2	15.1	16.4	13.7	12.1	17.5	15.2	9.6	13.8	14.9	10.0	13.0	12.7	10.7	11.2	12.0	11.8	10.0	12.9	2.26	17.5
	Yuma (Western)	14.5	14.9	14.1	16.7	14.3	13.5	13.5	16.2	14.3	13.8	15.8	20.5	14.3	16.3	17.5	16.8	17.5	19.5	15.7	2.05	13.0
	Maricopa	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

TABLE 2. CROP YIELD TRENDS WITHIN DESERT COUNTIES IN CALIFORNIA AND ARIZONA.

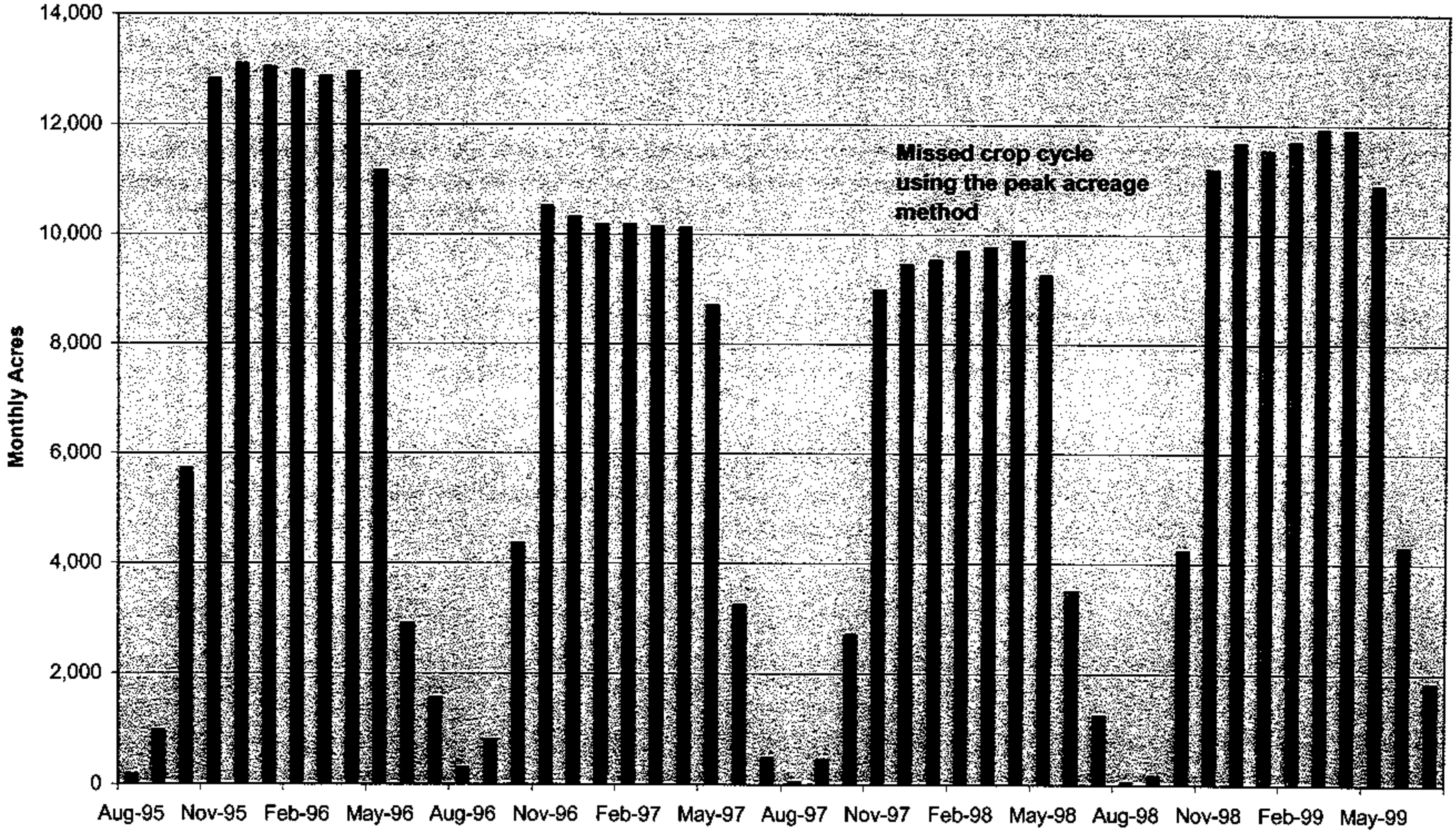
Source: California Agricultural Statistics Service
Arizona Agricultrual Statistics Service

Units: Tons/Acre; *Sorted by CV

Crop	County	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Avg	S[1]	CV[2]
Lettuce, Leaf	Maricopa	na	na	na	na	na	na	na	na	5.15	10.00	na	8.35	4.65	6.50	7.70	6.75	na	na	7.0	1.86	26.4
	Riverside	na	7.8	6.5	8.3	6.3	6.9	7.4	6.0	5.9	8.8	8.5	9.8	8.3	9.0	9.9	9.5	9.7	9.3	8.1	1.39	17.2
	Imperial	na	na	na	na	na	na	na	na	na	na	14.4	14.8	12.9	14.9	16.3	14.6	15.7	16.1	15.0	1.09	7.3
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Oranges (Navels)	Imperial	4.9	4.4	3.4	6.9	3.0	14.1	7.2	7.5	6.1	7.6	11.4	19.9	3.3	7.9	5.1	3.8	3.3	1.0	7.3	4.36	59.8
(Unspecified in some yrs)	Riverside	7.4	5.7	6.5	7.1	8.3	7.6	8.1	6.7	11.1	11.6	17.9	10.3	18.6	11.8	11.9	11.6	12.5	12.8	10.5	3.64	34.8
	Maricopa	3.5	4.5	5.0	9.1	5.5	5.5	3.3	4.9	6.2	5.3	5.0	2.8	5.3	4.0	2.7	6.0	6.3	4.9	5.0	1.50	30.0
	San Bernardino	5.3	6.8	5.1	11.2	9.6	9.5	9.0	13.0	10.9	10.9	12.6	8.1	15.3	12.3	11.9	11.5	11.4	11.3	10.3	2.67	25.9
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Tangerines	Maricopa	16.2	16.8	9.6	13.5	7.0	8.4	6.7	6.3	8.4	6.3	6.2	4.6	7.7	6.7	4.4	5.2	5.0	3.4	7.9	3.86	48.8
	Imperial	5.1	5.1	7.7	7.3	3.7	7.5	13.0	10.4	5.0	11.0	7.8	9.3	5.9	5.1	4.2	10.0	3.5	4.4	7.4	2.63	35.5
	Riverside	8.0	7.9	8.9	7.7	11.5	10.1	11.7	9.7	9.0	13.7	12.2	11.8	10.4	8.2	6.2	6.3	7.3	8.2	9.4	2.14	22.8
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Grapefruit	Maricopa	12.0	16.4	13.5	15.2	11.1	9.4	10.7	9.6	14.8	9.1	6.9	6.0	7.3	7.1	5.2	5.8	4.6	3.4	9.3	3.90	41.9
	San Bernardino	13.5	16.0	14.7	17.4	16.3	17.5	16.8	8.9	17.5	12.7	12.0	10.0	10.7	10.2	10.2	10.2	10.6	10.5	13.1	3.12	23.8
	Imperial	10.8	10.8	10.4	9.7	16.0	5.3	9.9	10.5	14.4	13.2	13.5	14.5	7.5	14.6	12.2	15.5	13.1	9.5	11.8	2.74	23.2
	Riverside	10.4	10.8	10.5	9.7	14.7	9.6	16.0	15.5	17.3	20.1	12.6	15.5	16.1	14.6	17.3	14.5	15.5	16.2	14.3	3.02	21.1
	Yuma	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Lemons	San Bernardino	35.8	46.7	27.2	17.2	7.4	11.3	11.3	1.9	3.5	7.7	9.6	8.3	7.9	8.0	7.9	15.0	3.3	4.8	13.0	11.95	91.7
	Maricopa	11.7	26.9	10.5	15.2	7.5	5.5	5.7	3.0	8.2	7.0	8.6	8.7	12.7	7.2	9.3	9.1	10.4	9.4	9.8	5.11	52.1
	Yuma	8.3	13.4	6.7	17.6	9.1	9.7	6.9	10.1	12.3	10.3	13.1	9.0	13.0	7.1	6.8	10.1	8.0	9.6	10.1	2.90	28.8
	Imperial	5.2	7.9	7.3	4.6	5.8	5.6	5.5	8.6	9.3	7.5	11.7	9.7	9.1	7.0	8.0	5.7	6.1	6.7	7.4	1.37	25.4
	Riverside	10.5	8.4	6.0	6.4	9.6	11.7	12.4	12.4	13.8	15.1	15.0	11.5	12.8	11.5	14.0	12.3	15.0	16.6	11.9	2.93	24.5

1 Standard deviation of the mean
2 Coefficient of variation (= (S / Avg)100)
3 Standard error of the mean (= S / (Square Root of n), where n = # of samples)

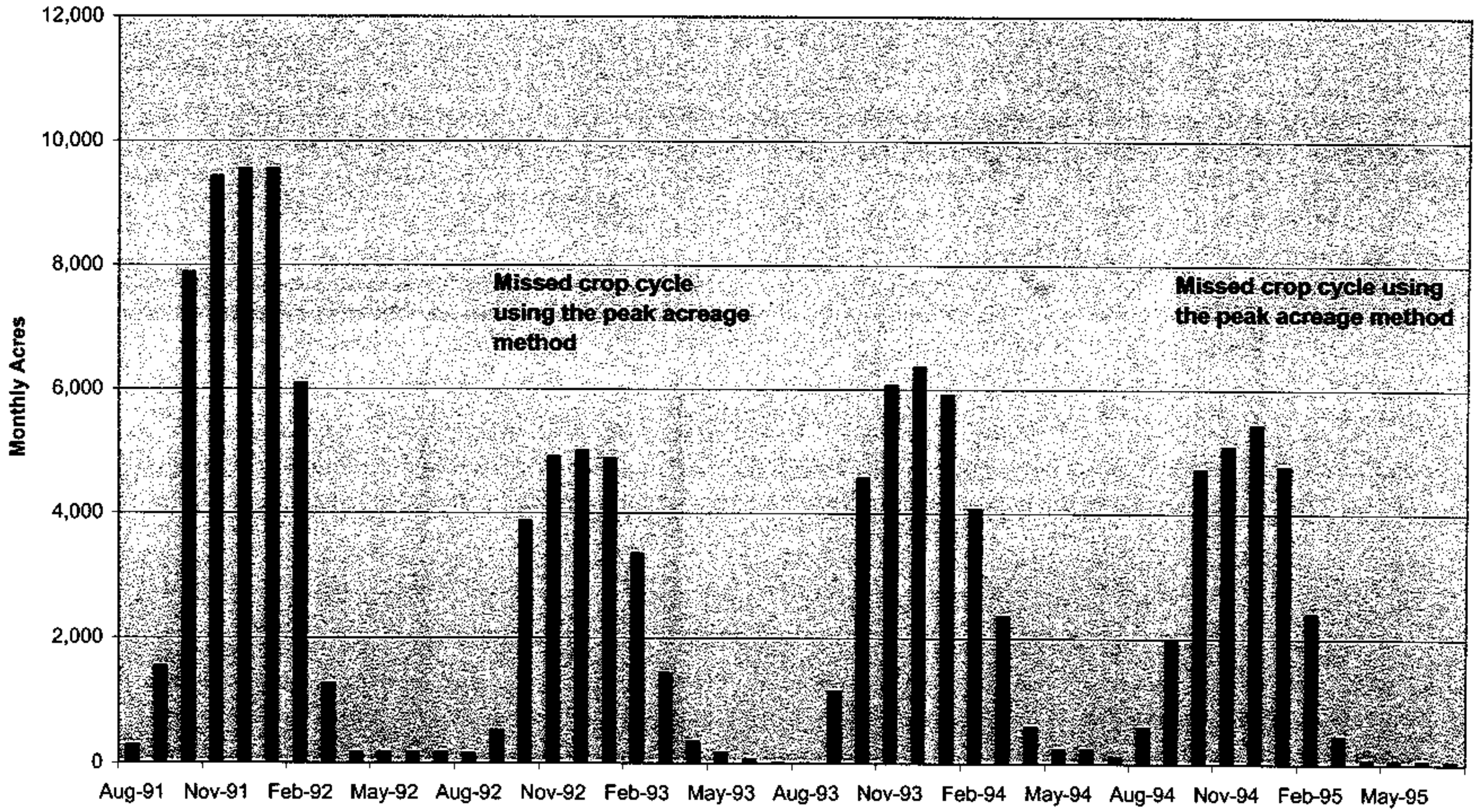
Figure 1. Comparison of Two Methods for Determining Annual Acreage of Onion Plantings in IID



Green = Crop Cycle Method (WST)

Red = Peak-Acreage Method (IID)

Figure 2. Comparison of Two Methods for Determining Annual Acreage of Broccoli Plantings in IID



Green (Black) = Crop Cycle Method (WST)

Red (Black) = Peak Acreage Method (IID)

Figure 3. IID Net Diversions of Colorado River Water and Irrigated Crop Acreage

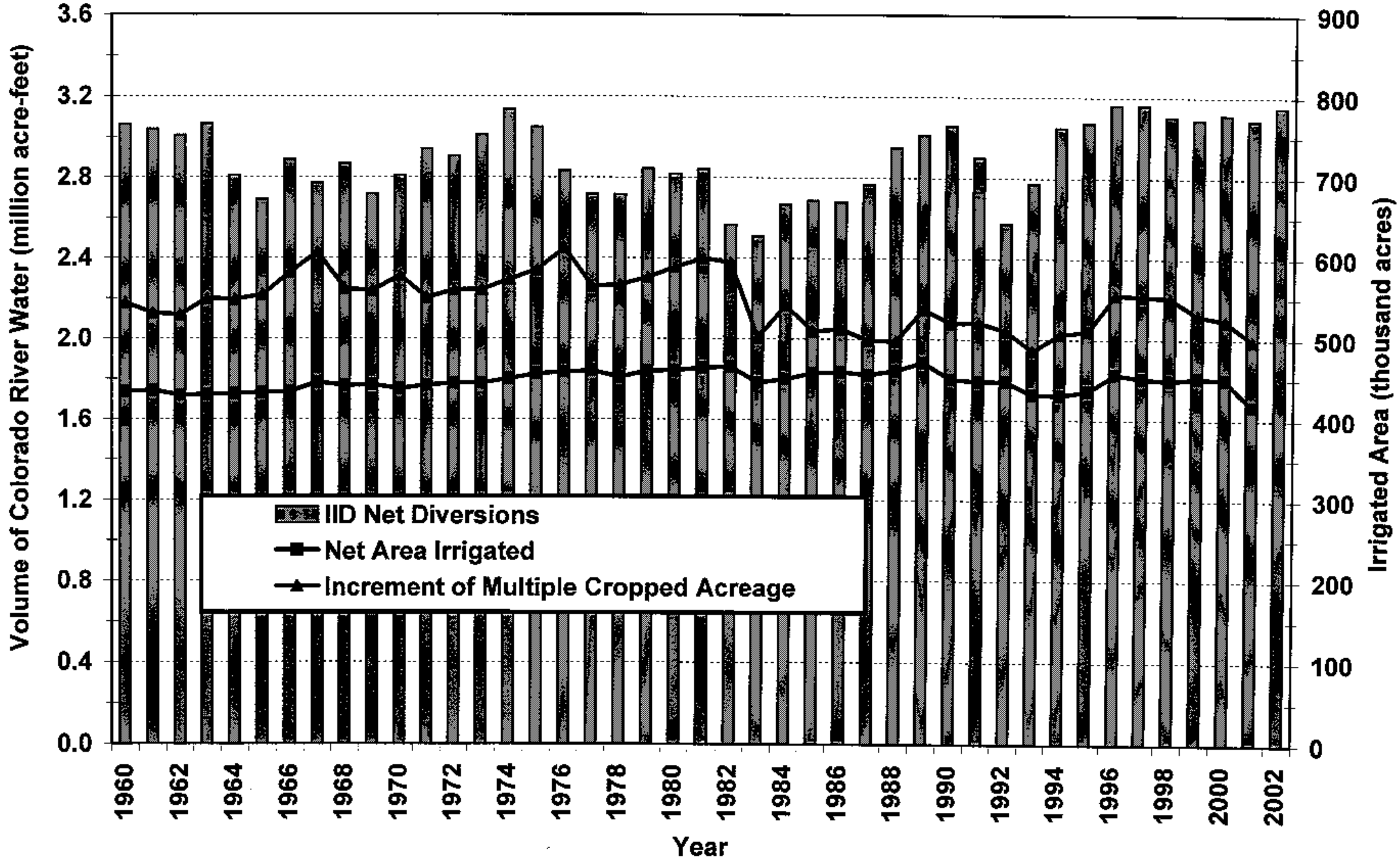


Figure 4. Idle Acres vs. Field & Garden Crop Acreage in IID

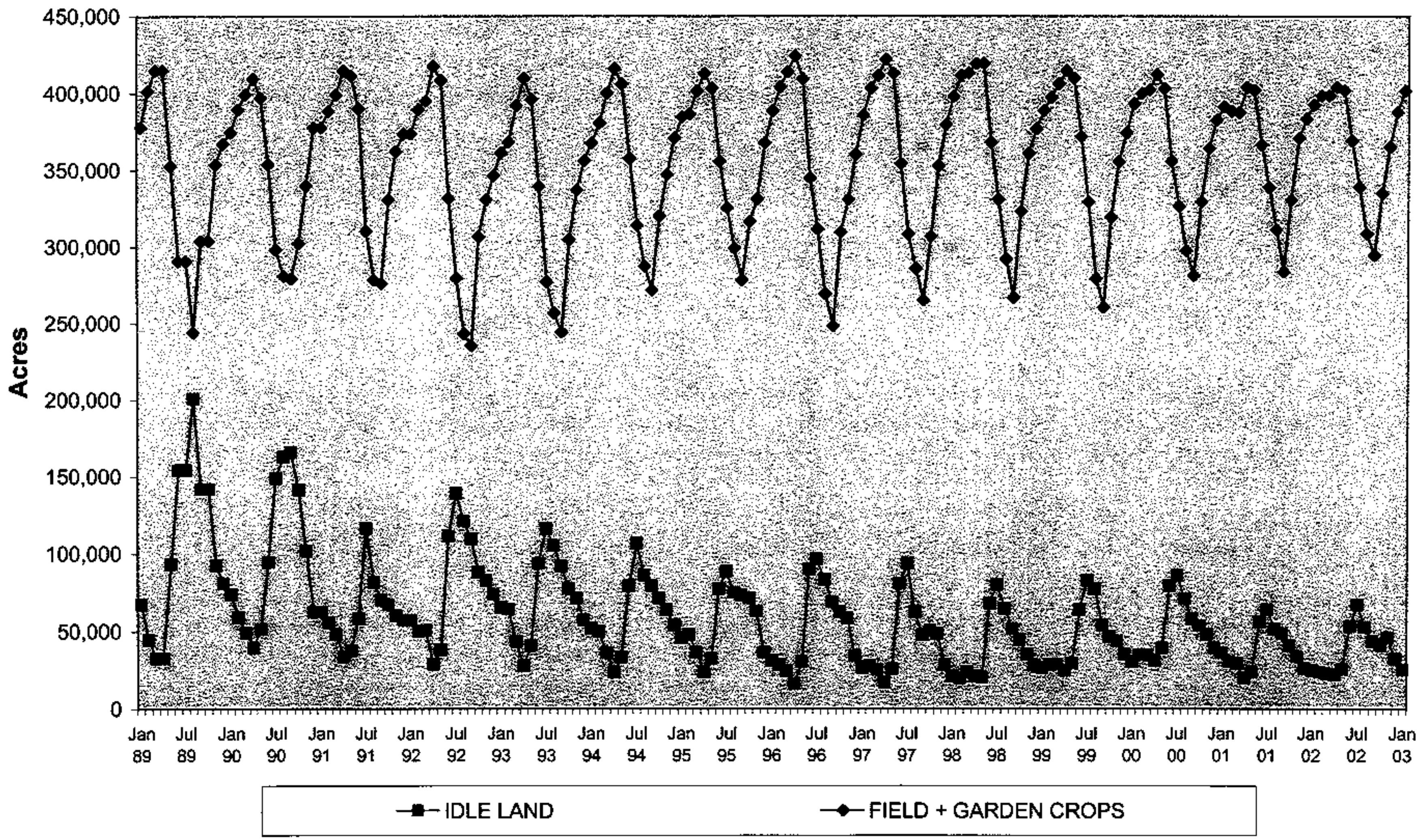


Figure 5. IID Net Diversions of Colorado River Water vs. Total Acres of Crops

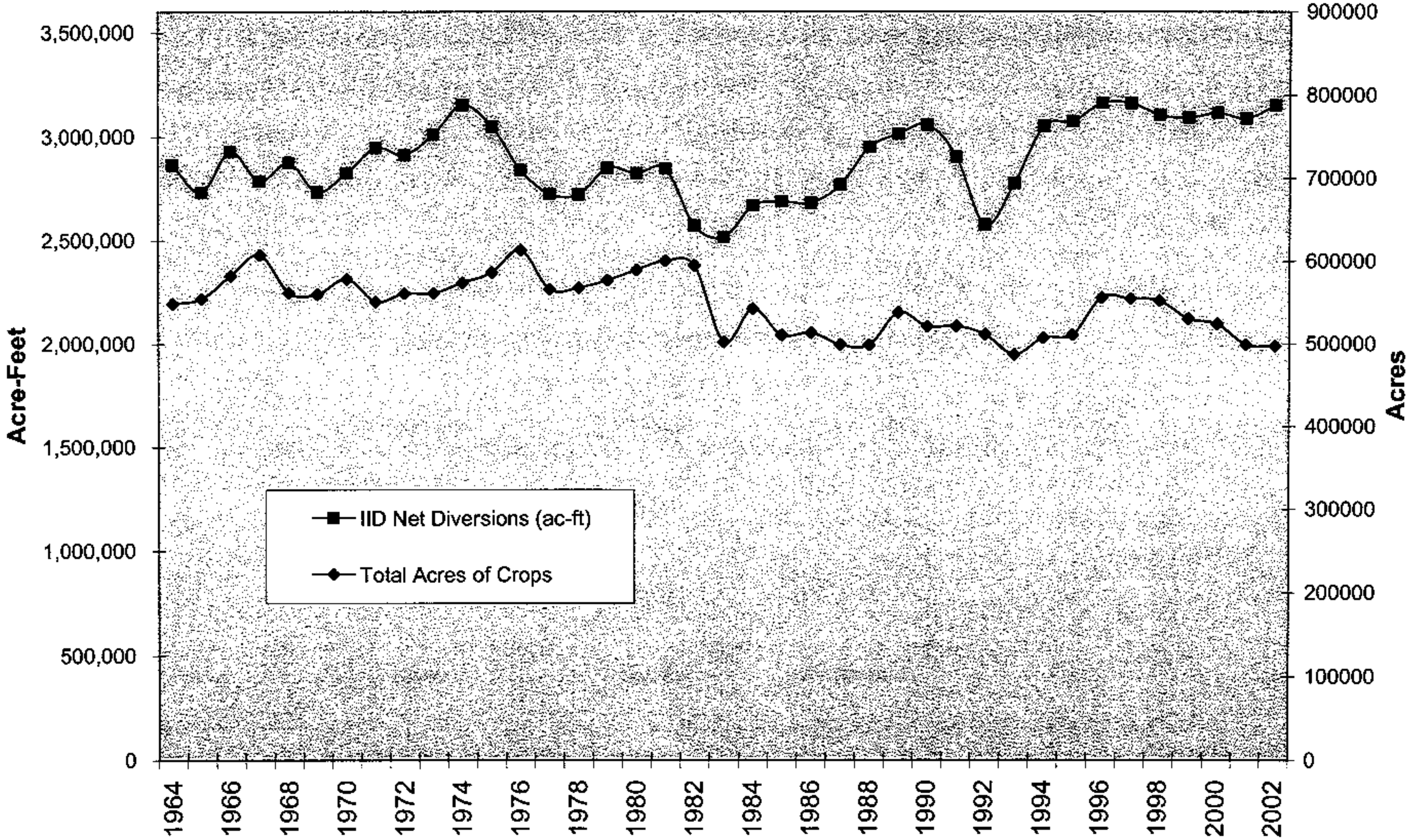


Figure 6. Yield Trends of Field Crops in Imperial County From 1980 through 2001

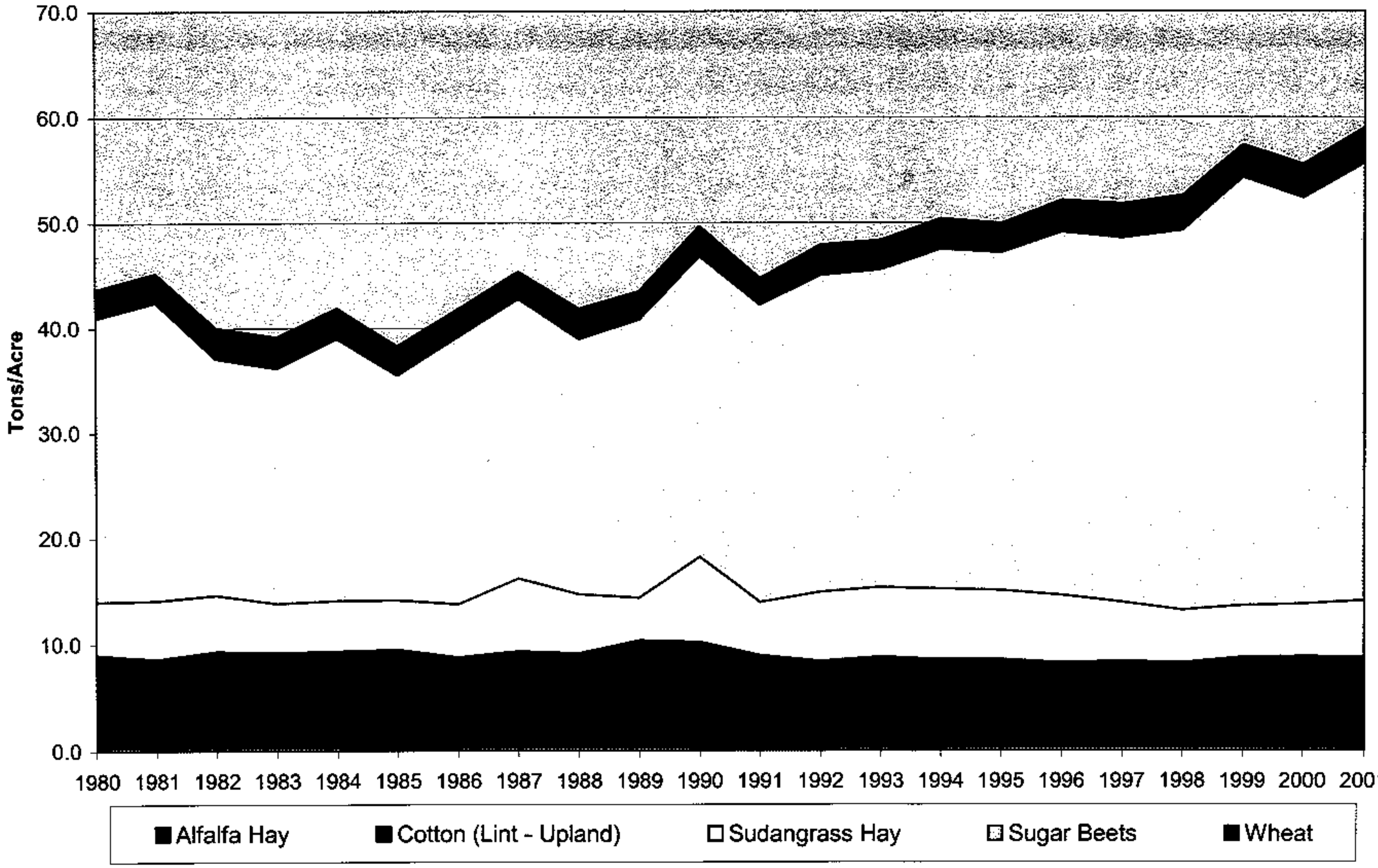


Figure 7. Yield Trends of Garden Crops in Imperial County From 1980 through 2001

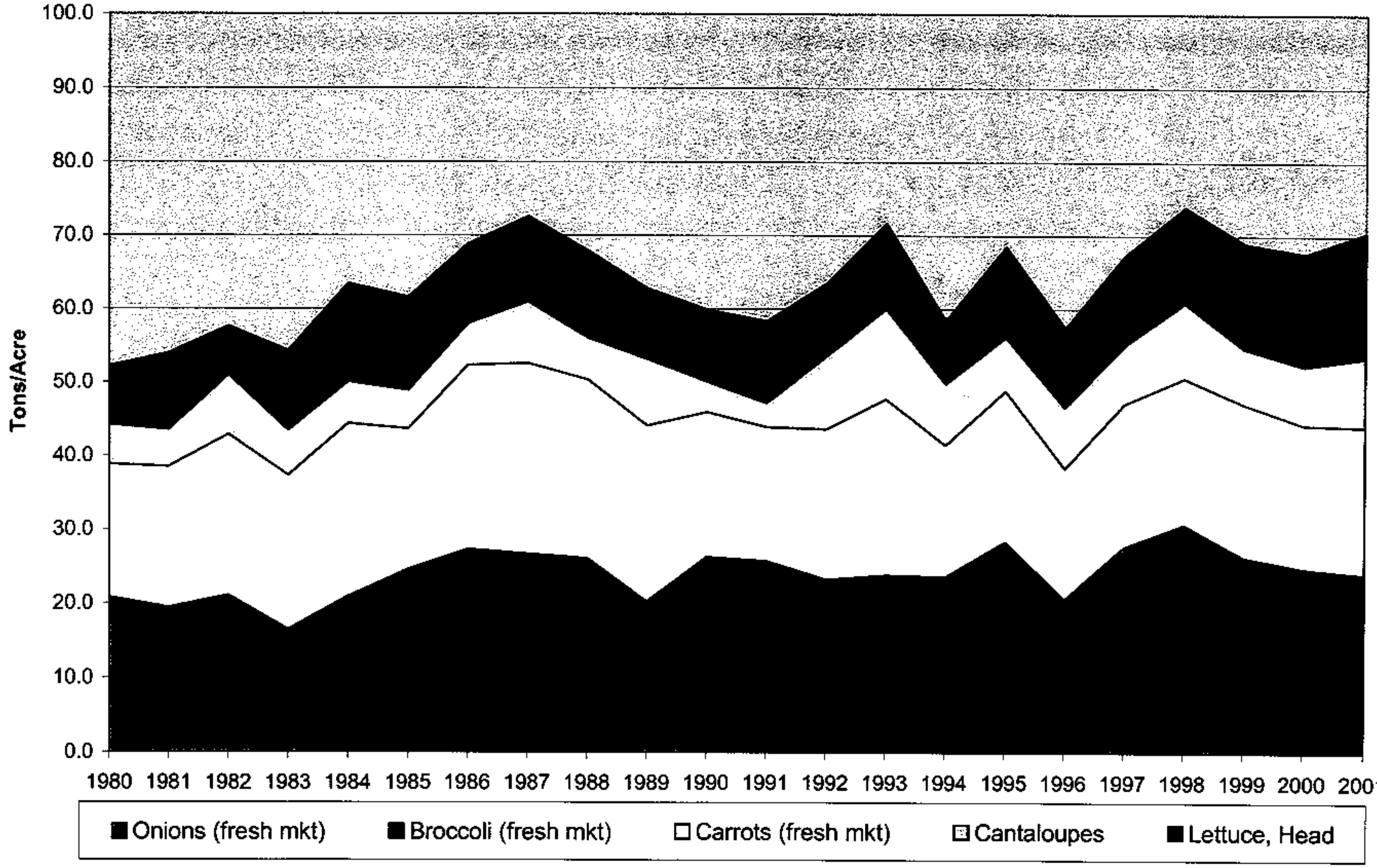


Figure 8. Yield Trends of Fruit Crops in Imperial County from 1980 through 2001

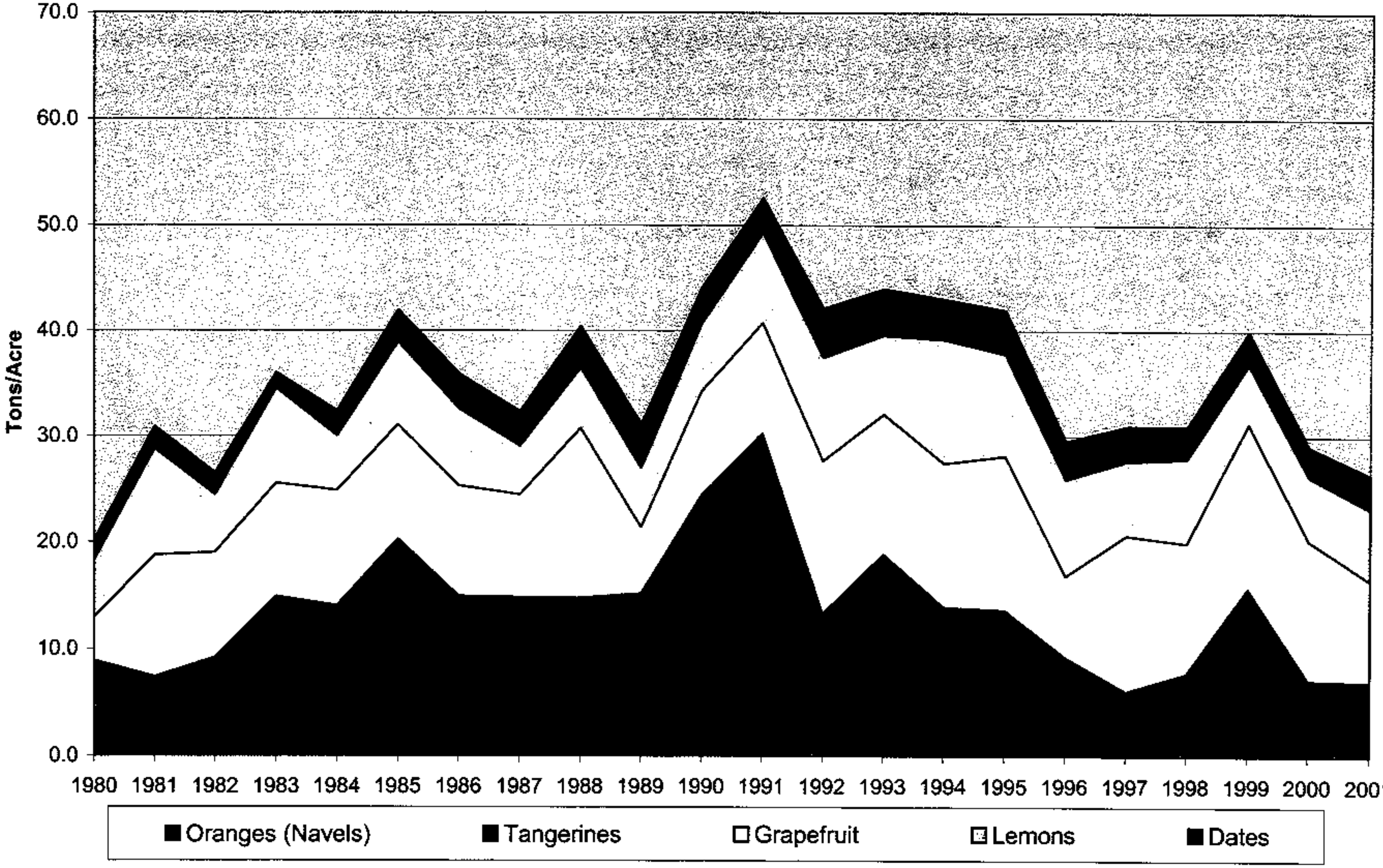


Figure 9. Annual Reference ETo for Three Cimis Stations in IID Compared to the Weighted Historic Average (Calipatria, Seeley, Meloland Stations)